Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band	)))	GN Docket No. 12-354

REPLY COMMENTS OF BARON SERVICES, INC.

Baron Services, Inc. ("Baron") submits these reply comments in response to the Notice of Proposed Rulemaking ("NPRM") released December 12, 2012 in the above-captioned proceeding[1] and the comments filed in response to the NPRM. Through the NPRM, the Commission proposes to create a new Citizens Broadband Service in the 3550-3650 MHz band ("3.5 GHz Band"). Baron manufacturers S-band weather radar systems certified by the Commission to operate within the 3500-3600 MHz frequency range.[2] Therefore, in its comments, Baron strongly urged the Commission to ensure that any new uses of the 3.5 GHz Band do not cause harmful interference to others operating on or adjacent to that spectrum. Despite the importance of identifying additional spectrum for wireless broadband applications, the Commission must not allow the expansion of unlicensed services to come at the expense of licensed users, particularly where, as here, those users provide critical public safety services.

These reply comments are supported by the attached Technical Analysis prepared by Bill Walker, Baron's Vice President and Chief Engineer. The Technical Analysis is intended to serve

[1] *See Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*, Notice of Proposed Rulemaking and Order, 27 FCC Rcd 15594 (2012). All comments cited herein are those filed on February 20, 2013 in GN Docket No. 12-354 in response to the NPRM.
[2] *See* Equipment Authorization Identification Nos. NX5VHDD-1000S and NX5KHDD-1000S.

as a supplement to the Fast Track Report,[3] and it follows the paragraph-by-paragraph organization of the ITU-R M.1461-1 recommendations.[4] However, unlike the Fast Track Report, the Technical Analysis bases its calculations on the operating parameters of Baron's S-band weather radar systems, which are more sensitive to interference than the radar systems analyzed in the Fast Track Report. In addition, while the Fast Track Report's calculations are based only on the operating parameters of WiMAX devices, the Technical Analysis contains calculations based on multiple antenna gains and power levels.[5]

As detailed in its comments, Baron is a pioneer in the field of dual-polarization radar technology, recently working with L-3 STRATIS to upgrade 171 Next Generation Weather Radar ("NEXRAD") systems to dual-polarization technology for the National Weather Service. In addition, as noted, Baron has developed a commercial dual-polarization radar system which is certified to operate in the 3500-3600 MHz band. Baron is currently finalizing the sale of two such systems to broadcast television stations that reach a combined population of over 8 million people, and Baron expects robust future demand for these systems because of the substantial advantages of operating an S-band dual-polarization radar system.[6] For instance, in contrast to traditional radar systems, which transmit a single horizontally-oriented radar pulse, dual-polarization radars also transmit a second, vertically-oriented pulse, which allows for far more accurate weather analysis, and thus can provide the public with substantially more accurate and

[3] *See* NTIA, *An Assessment of the Near-Term Viability of Accommodating Wireless Broadband Systems in the 1675-1710 MHz, 1755-1780 MHz, 3500-3650 MHz, 4200-4220 MHz, and 4380-4400 MHz Bands* (rel. Oct. 2010).
[4] *See* Technical Analysis at 3-4.
[5] Although the Technical Analysis uses the term "WiMAX," it does so generically. In reality, the calculations in the Technical Analysis are based on the theoretical operating parameters of small cell devices, not WiMAX. *See id.* at 3, n. 1 ("In this document, we use WiMAX as a global term to describe radios being considered for operating in the 3.55 GHz to 3.65 GHz frequency band, in both Fixed Base and Mobile/Portable applications.").
[6] *See id.* at 21(providing, as an example of the precision and system stability of dual-polarization weather radar systems, bias plots of horizontal and vertical polarization measurements "which demonstrate 1/100th dB stability and accuracy over a 3 day period.").

timely severe weather warnings and alerts. The benefits of dual-polarization radar systems are further increased by operating in the S-band because this spectrum provides less attenuation so radars can better look into the heart of a storm, and thereby more accurately gauge a storm's true potential. S-band radar systems operating in the Rayleigh region also provide significantly more backscatter to hail than the shorter wavelength of C-band (5 GHz) radar systems.

Commenters representing various industries agree with Baron that the Commission must ensure that Citizens Broadband Service operations in the 3.5 GHz Band do not cause harmful interference to other services. For instance, the National Cable & Telecommunications Association ("NCTA") emphasized that "the Commission must ensure that the technical and operational rules ultimately adopted [] protect adjacent licensed incumbent users from harmful interference."[7] Similarly, the National Association of Broadcasters stressed that, "if the Commission ultimately determines to establish this new service, then specific additional protections will be needed to safeguard incumbent C-band services from any harmful interference."[8]

Adequate protections are especially important due to the critical nature of the services, including weather radar, that are currently authorized to operate in or adjacent to the 3.5 GHz Band.[9] Baron therefore agrees with Harris Corporation that the Commission's proposal to permit Citizens Broadband Service operations in the 3.5 GHz Band "cannot be promulgated at the

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[7] Comments of National Cable & Telecommunications Association at 4 ("NCTA Comments").
[8] Comments of National Association of Broadcasters at 3; *see* Comments of Satellite Industry Association at i ("SIA Comments") ("If the Commission ultimately decides to pursue the introduction of small cells in the 3.5 GHz band, it must take steps to ensure that satellite services throughout the C-band are fully protected.").
[9] *See* Comments of Harris Corporation at 5 ("There are a variety of 'mission critical' facilities serving many industries across the country that require protection from interference…").

expense of incumbent users of the 3550-3650 MHz band, many of whom provide vital services serving critical infrastructure, the government, and the public interest at large."[10]

Baron also joins numerous commenters in urging the Commission to carefully analyze, through detailed technical analyses, the potential for harmful interference from Citizens Broadband Service operations and the efficacy of any potential service and technical rules intended to address this potential for interference. For instance, NCTA urged that, "[b]efore authorizing the proposed new service, the FCC should ensure, through rigorous analysis of technical studies, that harmful interference will be avoided."[11] Baron further agrees that "[t]he Commission should seek comment on any such studies and tests, as well as any specific implementation and/or mitigation proposals it may advance following their completion."[12]

As Baron explained in its comments, technical and service rules that adequately prevent the introduction of harmful interference also are necessary to protect the good faith investments Baron and others made in reliance on the current allocations for the 3.5 GHz Band and the Commission's grant of equipment authorizations. Similarly, SIA noted that "FSS networks in the 3.5 GHz band represent a substantial long-term investment in satellite capacity and associated ground equipment."[13] Accordingly, SIA urged the Commission to "ensure that investment is not stranded as a result of any action taken to promote small cell deployment."[14]

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[10] *Id.* at 2; *see* SIA Comments at 10 ("The Commission should only consider permitting small cell deployment in the 3.5 GHz band if it is demonstrated that satellite services will be protected now and in the future.").

[11] NCTA Comments at 2; *see* Comments of Alcatel-Lucent at 14 ("Alcatel-Lucent cautions that detailed technical studies using simulation tools and testbeds are essential…"); SIA Comments at i ("[B]efore considering changes to the regulatory approach in this band … there must be technical data demonstrating that the proposed small cells can operate without impairing current or future C-band satellite services.").

[12] NCTA Comments at 6.

[13] SIA Comments at 12.

[14] *Id.*

Carefully crafted technical and service rules based on detailed technical analyses are particularly necessary to protect radar operations, including weather radar systems. This is because, as Baron detailed in its comments, radars must employ very sensitive receivers in order to receive and process the portions of transmitted energy that reflect off of the small, remote objects they are designed to accurately detect. As a consequence, all radars, and weather radars in particular, are highly sensitive to interference. Weather radars and WiMAX devices cannot operate co-channel or close to the radar carrier ("CTC") under any reasonable operational scenario because the receiver in both systems will be saturated and possibly damaged.[15]

Baron's comments also noted that, while filters installed on weather radar receivers can reject or suppress interference from the in-band transmissions of other radars, they are not effective against communication-signal out-of-band emission ("OOBE") interference because such interference typically is above the threshold of the radar receiver and is of much higher duty cycle than radars. As a result, Baron explained that a substantial geographic exclusion zone around each radar site, within which CTC Citizens Broadband Service base stations and mobile devices could not operate, would be required to prevent harmful interference. As demonstrated in the attached Technical Analysis, Baron's additional calculations further support this finding – *i.e.*, that substantial exclusion zones would be needed to prevent Citizens Broadband Service devices operating CTC with weather radar systems from causing harmful interference to such radar systems.[16]

Baron further explained that its radar systems also would be highly susceptible to interference caused by the OOBEs of Citizens Broadband Service operations. Other

[15] *See* Technical Analysis at 9 & 16.
[16] *See id.*

commenters, like the Commission,[17] similarly recognized the substantial potential for OOBE interference caused by Citizens Broadband Service operations in the 3.5 GHz Band. For instance, Harris Corporation noted that a "primary concern for incumbent users in the 3.5 GHz and adjacent bands is the issue of interference caused by out-of-band emissions…"[18] As a result, Baron again strongly urges the Commission to address this potential form of harmful interference using a combination of exclusion zones around weather radar sites and adequately stringent OOBE limits for Citizens Broadband Service transmitters.[19]

Notably, there is a direct correlation between the OOBE limit imposed upon Citizens Broadband Service transmitters and the size of the necessary exclusion zones around weather radar systems. In other words, stringent OOBE limits would significantly decrease the size of the requisite exclusion zones. Such an approach therefore would be consistent with the Commission's desire "to reduce any exclusion zones through technical and operational parameters,"[20] as well as address commenters' concerns regarding the size of exclusion zones.[21]

The attached Technical Analysis demonstrates the relationship between OOBE limits and the size of exclusion zones. Specifically, assuming a frequency offset of 25 MHz, and using the operating parameters of Baron's dual-polarization radar systems and the potential operating

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[17] *See* NPRM, 27 FCC Rcd at 15637 ("Transmissions originating in the 3.5 GHz Band may cause harmful interference to other services operating in the adjacent bands.").
[18] Comments of Harris Corporation at 2; *see* SIA Comments at 18 ("SIA emphasizes that adoption and enforcement of appropriate measures to address out-of-band emissions are critical to protect ongoing C-band satellite operations.").
[19] *See* SIA Comments at 20 ("In general, a combination of out-of-band emission limits and exclusion areas will be required to protect FSS earth stations which receive on adjacent frequencies to small cell transmissions.").
[20] NPRM, 27 FCC Rcd at 15631.
[21] *See* Comments of Utilities Telecom Council, Edison Electric Institute, and National Rural Electric Cooperative Association at 12 ("Reducing the exclusion zones will be critical for the effective use of the 3.5 GHz Band…"); Comments of Telecommunications Industry Association at 2 ("Further efforts aimed at quantifying and reducing the exclusion zones for many major US population centers … should be undertaken collaboratively between interested parties if the Commission seeks to pursue a mobile use.").

parameters for Citizens Broadband Service transmitters, an OOBE limit of 65 dB would require an exclusion zone around weather radar sites of only 1 kilometer.[22] Alternatively, by adopting a slightly larger 5 kilometer exclusion zone, this OOBE limit could be reduced by 14 dB while still adequately protecting weather radars from harmful OOBE interference.[23] Clearly, the Commission's proposed OOBE limit of $43 + 10 \log_{10} (P)$ dB[24] would be woefully insufficient absent large exclusion zones.[25] Baron also notes that the small exclusion zones that would be needed if the Commission imposes more stringent OOBE limits likely would not be in high traffic areas because Baron's radar systems normally will be located well outside metropolitan areas (perhaps 30-40 miles outside of the relevant downtown area).

Based on the attached Technical Analysis, Baron therefore again asserts that the best approach would be for the Commission to adopt a relatively stringent OOBE limit in conjunction with smaller, but sufficient, exclusion zones. Otherwise, the Commission would either effectively prohibit Citizens Broadband Services in many parts of the country or permit harmful interference to weather radar services, and thereby endanger the public that relies on the life-saving information provided by these services. Moreover, as Baron noted in its comments, this approach would not unduly burden 3.5 GHz Band users or equipment manufacturers because compliance with a more stringent OOBE limit can be accomplished by installing filters in Citizens Broadband Service base stations and mobile devices that, with the benefit of economies of scale, likely would add only a few dollars to equipment costs.

[22] *See* Technical Analysis at 16.
[23] *See id.*; *see also* Comments of Motorola Solutions, Inc. at 8 ("Devices with less stringent transmit spectral masks should not be allowed to operate as close to protected incumbents as devices with better spectral masks.").
[24] *See* NPRM, 27 FCC Rcd at 15638.
[25] *See* SIA Comments at 20 ("[G]iven the sensitivity of conventional C-band receivers, the out-of-band emission limit in the Notice may be inadequate and may therefore lead to large exclusion areas, even with respect to adjacent frequency operations.") (internal citation omitted).

In sum, Baron continues to strongly urge the Commission to adopt service and technical rules that fully protect all future S-band weather radar systems operating within the 3500-3600 MHz band from the harmful interference that otherwise would result from Citizens Broadband Service operations in the 3.5 GHz Band. Specifically, the Commission should: (1) establish substantial exclusion zones to mitigate interference to CTC radar operations; and (2) authorize smaller exclusion zones in situations where Citizens Broadband Service operations can take advantage of frequency offset, power level adjustments, antenna gain, and filtering capabilities in order to prevent interference to adjacent channel radar operations. By doing so, the Commission would promote the public interest by ensuring the continued viability of these advanced weather radar systems while at the same time increasing the amount of spectrum available for wireless broadband services.

Respectfully submitted,

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Table of Contents

Determining Interference Between Weather Radars and WiMAX[1] Operating in the Proposed 3.5GHz Frequency Band

NPRM 3.5-3.6GHz Weather Radar Adjunct Proposal

1. Introduction

Baron Services, located in Huntsville, Alabama, is a privately owned business engaged in the design, development and production of weather radar systems and weather display.

One of Baron's most notable recent accomplishments was the design and development of the NEXRAD Dual-Polarization Upgrade, consisting of 171 systems, for the National Weather Service, FAA and Department of Defense (DoD).

Weather radar is a lifesaving sensor which serves the 300+ million U.S. citizens on a daily basis. Severe weather affects each of us in all facets of our daily lives. Thus, we respectfully request that weather radar systems operating in the 3.5GHz - 3.6GHz frequency band be considered for interference protection in this FCC Notice of Proposed Rule Making (NPRM) proceeding.

1.1 DoD Radar/WiMAX Exclusion Zones and Location

Baron collaborated with the DoD in developing our 3.5GHz - 3.6Ghz weather radar system and has obtained complete interoperability with DoD radars[2] working in this frequency band. As presented in the NPRM, any WiMAX exclusion zones in protected DoD areas apply directly to Baron weather radar systems as well, since we already have interoperability with the DoD radar systems.

1.2 Adjunct Proposal for NPRM Proposed 3550MHz -3650MHz Broadband Wireless and Weather Radar Systems Operating in the 3500MHz – 3600MHz Frequency Band

This document is being submitted to the FCC as an adjunct proposal to the Fast Track Report.[3] Our proposal regards the assessment of ground based Weather

[1] In this document, we use WiMAX as a global term to describe radios being considered for operation in the 3.55GHz to 3.65GHz frequency band, in both Fixed Base and Mobile/Portable applications.

[2] Baron-DoD radar operability in effect for all locations except: Within 65km of Pascagoula, Miss., Pensacola, Fl., and Indian Head, Md. Baron must address installations in these exclusion zones with DoD on a case-by case basis.

[3] *See* NTIA, *An Assessment of the Near-Term Viability of Accommodating Wireless Broadband Systems in the 1675-1710 MHz, 1755-1780 MHz, 3500-3650 MHz, 4200-4220 MHz, and 4380-4400 MHz Bands* (rel. Oct. 2010) ("Fast Track Report") (available at http://www.ntia.doc.gov/files/ntia/publications/fasttrackevaluation_11152010.pdf).

Radar Systems operating in the 3500MHz -3600MHz frequency band and the proposed addition of 3550MHz -3650MHz frequency band Wireless Communications Systems (WiMAX).

Baron's proposal is directed toward the following identifiers in the Fast Track Report:

- Page 1-4, Summary of Results 3550MHz-3650MHz Geographic Limitations
- Pages 4-80/86 regarding WiMAX to Radar Interference and conversely Radar to WiMAX Interference
- Appendices A, D, E & F

Baron's analysis follows the paragraph-by-paragraph organization of the ITU-R M.1461-1 recommendations. Since we do not have the actual WiMAX Data Sheet specifications, we attempted to use the same or similar estimates described in the Fast Track Report.

Baron's analysis also includes sample calculations demonstrating how frequency offset, geographic separation, power level adjustments, antenna gain selection and filtering capabilities are factors which can be used to mitigate harmful interference to commercial weather radars operating in the 3.5-3.6 GHz band from WiMAX operations in the partially overlapping 3.55-3.65 GHz band.

1.3 Proposal Presentation Summarized

Radar to WiMAX and WiMAX to Radar On-Tune and Off-Tune Analysis, Technical Characteristics and assumptions:

- Baron KHDD-1000S-K/DP S-Band Weather Radar Specification, <u>Attachment A</u>
- WiMAX Antenna, Laird 18dBi Gain[4], <u>Attachment B</u>
- Weather Radar and Broadcasters Save Lives, <u>Attachment C</u>

<u>Proposal Conditions and Assumptions:</u>

- o WiMAX Base Station, generic 10 Watts or 40dBm (worst case)
- o Direct coupling between the transmit and receive antennas (worst case)
- o On-Tune radar transmit power to be 90dBm in single-polarization, minus losses stated (worst case)
- o Off-Tune radar transmit power Out of Band (OOB) to be -60dBC
- o Determined the OOB filter characteristics for the WiMAX transmit and receive functions

[4] 18dBi is considered a worst-case scenario. Plots are provided for 18dBi, 6dBi, 3dBi and 0dBi in section 2.2 of the text as an example.

- Graphed the Radar receiver RF-IF receiver rejection in 1MHz bandwidth
- Graphed the radar WiMAX separation requirements for each case analyzed
- Employed 1MHz receiver bandwidth in all interference calculations

2. Interference from Weather Radar Systems to WiMAX Devices

2.1. Receiver Front-end Overload

2.1.1. Assessing Receiver Front-end Overload

$$T = C - G \qquad (1)$$

We have no input to this paragraph other than to acknowledge that the Fast Track Report used -30dB for saturation and 0dBm for burn out. We believe the WiMAX provider has to provide this response to (1) above.

$$I_t = T - FDR_{if} \qquad (2)$$

We have no comment on this paragraph except the WiMAX provider has to respond to this formula (2) above.

$$I = P_T + G_T + G_R - L_T - L_R - L_P \qquad (3)$$

$I = 44.7dBm$

where:

$I = 44.7dBm, Peak\ Power\ of\ Radar\ Pulses$

$P_T = 90dBm, Peak\ Power\ of\ Radar\ Transmitter$

$G_T = 45dB, Main\ Beam\ Antenna\ Gain$

$G_R = 18dBi, Receive\ Antenna\ Gain$[5] $in\ Direction\ of\ Radar$

$L_T = 3dB, Loss\ of\ RadarTransmitter$

[5] We are assuming 18dB antenna gain as the full gain of the WiMAX Base Station. For a different antenna gain the number must be adjusted dB for dB.

$L_R = 2dB, Insertion\ Loss\ of\ WiMAX\ Receiver$

$L_P = 103.3dB, Propagation\ Path\ Loss\ between\ Radar\ and\ WiMAX\ Antennas$

where:

$$L_P = 20\log(d_{km}) + 20\log(f_{mhz}) + 32.44dB \tag{3.1}$$

Then for 1km separation at 3500MHz;

$L_P = 0 + 70.88 + 32.44 = 103.32dB$

$L_P = 103.32$

2.2. Radar Transmitter Emission Coupling

2.2.2. Radar Emission Interference

$$I_T = 1/n + N \tag{4}$$

$I_T = 1 + (-106.4) = -105.4dBm$

where:

$\frac{1}{n} = 1dB, Interference\ to\ Noise$

$N = -168.6dBm + 10logB_{if} + 10logT = -106.4dBm$

where ;

$B_{if} = 5000_{khz} = 37dB$

$T = 290degK = 24.6dB$

$I_t = C -$ (C/I) Optional Calculation Omitted (5)

<u>Then for On-Tune Condition</u>:

$$I = P_T + G_T + G_R - L_T - L_R - L_P - FDR_{if} \tag{6}$$

$I = 44.7dBm, On - Tune\ Condition$

Where:

$I = 44.7dBm, Peak\ Power\ of\ Radar\ Pulses$

$P_T = 90dBm, Peak\ Power\ of\ Radar\ Transmitter$

$G_T = 45dB, Main\ Beam\ Antenna\ Gain$

$G_R = 18dBi, Receive\ Antenna\ Gain$[6] $in\ Direction\ of\ Radar$

$L_T = 3dB, Loss\ of\ RadarTransmitter$

$L_R = 2dB, Insertion\ Loss\ of\ WiMAX\ Receiver$

$L_P = 103.3dB, Propagation\ Path\ Loss\ between\ Radar\ and\ WiMAX\ Antennas$

$FDR_{if} = 0dB, On - Tune\ Condition$

<u>For WiMAX Off-Tune condition of 25MHz:</u>

$$WiMAX\ FDR_{if}(25MHz) = OTR + OFR(\Delta f) \tag{6.1}$$

WiMAX $FDR_{if}(25MHz) = (-16dB) + (105.4)$

$WiMAX\ FDR_{if}(25MHz)$ = -89.4dB @ 25MHz Off-Tune

Additional loss for 5km spatial separation (20log5) = 14dB

Thus,

$-89.4 + 14 = -75.4dB\left(FDR_{if}\right)@\ 5km$

where:

$OTR = Off - Tune\ Emission\ of\ Radar$

OTR =I -60dBC

OTR =44dBm -60dB

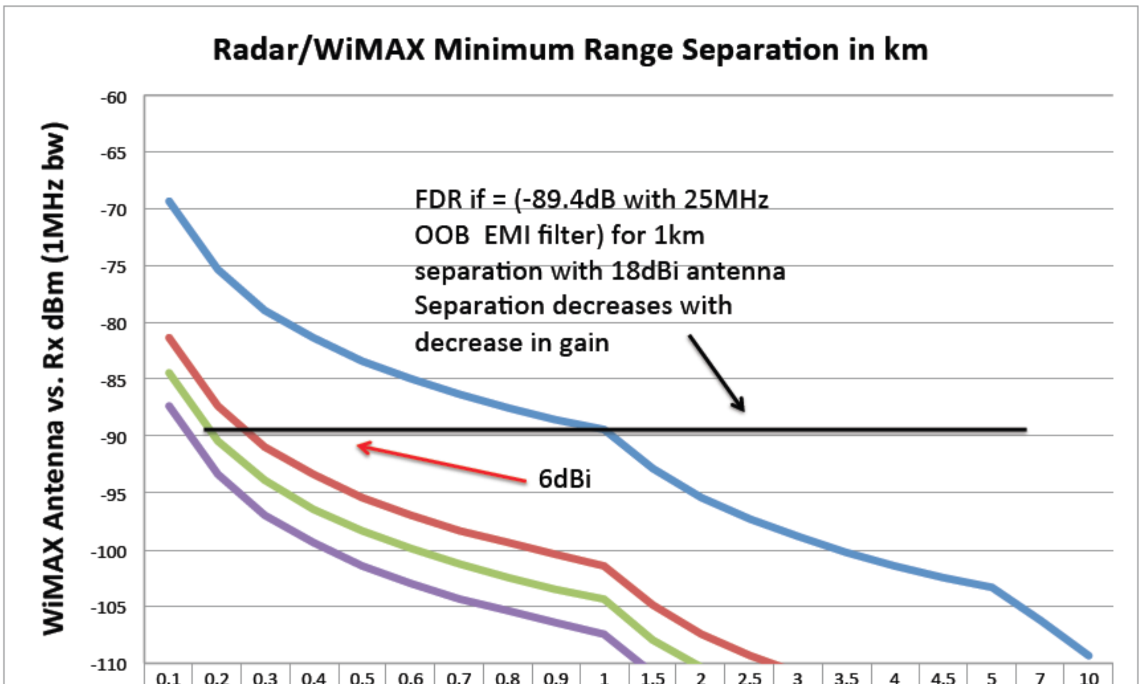
OTR =-16dBm

[6] We are assuming 18dB antenna gain as the full gain of the WiMAX Base Station. For a different antenna gain the number must be adjusted dB for dB.

$$OFR = Off - frequency\ rejection\ of\ WiMAX$$

$$OFR_{required} = -105.4dB + 16dB$$

$$OFR_{required} = -89.4dB\ @\ 1km\ spatial\ separation$$



	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.5	2	2.5	3	3.5	4	4.5	5	7	10
18dBi	-69.4	-75.4	-78.9	-81.4	-83.4	-85.0	-86.3	-87.5	-88.5	-89.4	-92.9	-95.4	-97.4	-98.9	-100.	-101.	-102.	-103.	-106.	-109.
6dBi	-81.4	-87.4	-90.9	-93.4	-95.4	-97.0	-98.3	-99.5	-100.	-101.	-104.	-107.	-109.	-110.	-112.	-113.	-114.	-115.	-118.	-121.
3dBi	-84.4	-90.4	-93.9	-96.4	-98.4	-100.	-101.	-102.	-103.	-104.	-107.	-110.	-112.	-113.	-115.	-116.	-117.	-118.	-121.	-124.
0dBi	-87.4	-93.4	-96.9	-99.4	-101.	-103.	-104.	-105.	-106.	-107.	-110.	-113.	-115.	-116.	-118.	-119.	-120.	-121.	-124.	-127.

Radar to WiMAX Off-Tune (25MHz) Spatial Separation (km) Requirement Plotted Against Different WiMAX Antenna Gain

Thus the receive filter of the WiMAX must have 89.4dB of rejection at 25MHz offset for 18dBi antenna gain, for outside operation and a spatial separation of 1km, with direct antenna coupling.

Recommendations

In summarizing the above calculated interference values between the Weather Radar and WiMAX the following applies:

- We used a 1MHz bandwidth (-105.4dBm noise floor) for these calculations. Bandwidth corrections must be applied for the appropriate data bandwidths (WiMAX receiver bandwidths).
- We applied the maximum gain of the antennas, 45dB for the Weather Radar and 18dB for the WiMAX.
- The Weather Radar to WiMAX On-Tune requires a large spatial separation and is not considered applicable in any scenario of interoperability we can envision.
- The WiMAX and Radar needs to be spatially separated (see above plot), and Off-Tuned, by at least 25MHz in frequency.
- The WiMAX receiver filter rejection at 1km separation calculates -89dB.
- The rejection requirement can be lowered 14dB by 5km separation.
- De-coupling of the antenna beams can lower the WiMAX receiver filter requirement.
- The WiMAX can "globally" be considered as a helicopter hovering at the tower height (AGL) over the local terrain in site-specific locations and will surely come in direct contact with the radar main beam if not accounted for in the WiMAX site planning analysis.
- Radar siting becomes more complex when the WiMAX infrastructure is already in place and must be accounted for in the FCC's final rules to obtain interoperability in all future site scenarios. This problem needs to be solved locally by the parties involved.
- In complex scenarios, the WiMAX antenna may not be able to be pointed toward the Weather Radar due to separation requirements, leaving a gap in coverage that, if filled, will have to be accomplished with a low power repeater.
- WiMAX must employ Diverse Frequency Selection (DFS) to determine if a radar system is operating in the WiMAX band. The DFS look-thru must be capable of detecting a radar RF pulse with maximum PRI of 4 milliseconds and a maximum 3db radar emission bandwidth of 2MHz (0.5usec pulse).
- Spectrum Access Systems (SAS) must be employed in the WiMAX device and be used in conjunction with a location (GPS) database to control permission and operating parameters. WiMAX must be cataloged into the database at installation time.

3. Interference to Weather Radars from WiMAX

3.1. Receiver Front-end Overload

3.1.1. Front-end Saturation

Degradation of the Weather Radar receiver due to interference from the WiMAX emissions are calculated as follows:

$$P_{I_{RF\,max}} = P_{1_{dB}} + K_{sat} = C - G + K_{sat} \qquad \text{dBm} \qquad (12)$$

$$P_{I_{RF\,max}} = C - G + K_{sat}$$

$$P_{I_{RF\,max}} = 13 - 34 + (-6)$$

$$P_{I_{RF\,max}} = -27dBm$$

where:

$P_{I_{RF\,max}} = -27dBm\ Maximum\ allowed\ total\ interference\ inside\ RF\ bandwidth$

$K_{sat} = -6dB, saturation\ margin\ (dB) for\ Weather\ Radar$

$P_{1_{dB}} = 1db - input\ compression\ point$

$C = 13dB, output\ 1dB\ gain\ compression\ point$

$G = 34dB, gain\ of\ the\ LNA$[7]

On-Tune front-end overload occurs when:

$$I_T > P_{I_{RF\,max}} - FDR_{rf} \qquad (13)$$

$I_T = -27dBm\ or\ higher$

Incompatible without excessive spatial separation

where:

$I_T = -27dBm, Interference\ signal\ level\ at\ the\ radar\ LNA\ input$

[7] This calculation is for a 14bit digital receiver. For a 16bit digital receiver the LNA is 24dB gain and the I_t is increased by 10dB to -17dBm.

$FDR_{rf} = 0dB, On - Tune\ Frequency\ dependent\ rejection\ of\ WiMAX\ emission$

<u>Off-Tune 25MHz front-end overload calculation:</u>

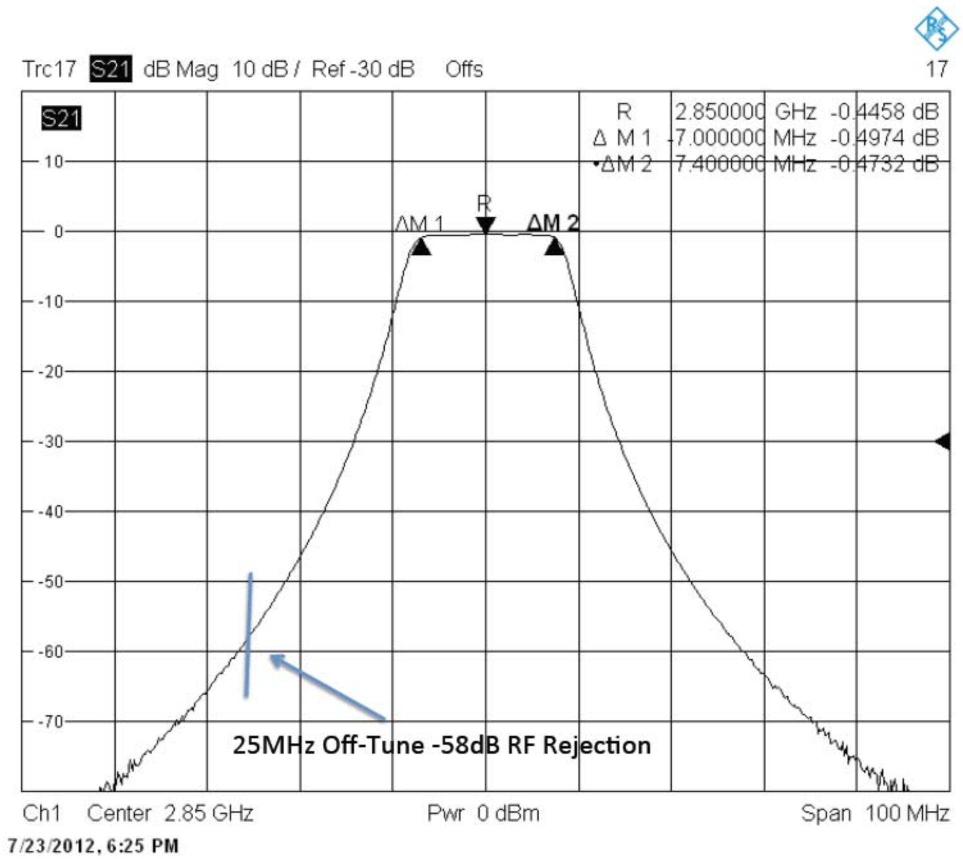
$$I_T > P_{I_{RF\,max}} - FDR_{rf} \quad (13.1)$$

$$I_T = -85dBm$$

where:

$I_T = -27dBm, Interference\ signal\ level\ at\ the\ radar\ LNA\ input$

$FDR_{rf} = -58dB, Off - Tune\ Radar\ FDR\ of\ WiMAX\ emission$



Weather Radar Receiver (2.85GHz Example) EMI Filter Plot

<u>Interference On-Tune Calculation</u>

$$I = P_T + G_T + G_R - L_T - L_R - L_P \quad (14)$$

$$I = -3.7dBm\ On - Tune$$

where:

$I = Peak\ Power\ of\ WiMAX\ Interference$

$P_T = 40dBm, Peak\ Power\ of\ WiMAX\ Transmitter$[8]

$G_T = 18dBi, WiMAX\ Main\ Beam\ Antenna\ Gain$

$G_R = 45dBi, Radar\ receive\ Antenna\ Gain$

$L_T = 2dB, Loss\ of\ WiMAX\ Transmitter$

$L_R = 1.4dB, Insertion\ Loss\ of\ Radar\ Receiver$

$L_P = 103.3dB, Propagation\ Path\ Loss\ between\ WiMAX\ and\ Radar\ Antennas$

where:

$$L_P = 20\log(d_{km}) + 20\log(f_{mhz}) + 32.44dB \qquad (14.1)$$

Then for 1km separation at 3500MHz;

$$L_P = 0 + 70.88 + 32.44 = 103.32dB$$

$$L_P = 103.32$$

3.2. Degradation of Sensitivity

$$I_T = 1/n + N \qquad (15)$$

$$I_T = 1 + (-106.4) = -105.4dBm$$

where:

$\frac{1}{n} = 1.26dB$ [9]

$N = -114dBm + 10logB_{Mhz} + NF = -113.25dBm$

where ;

$N = -114dB\ in\ 1MHz\ bandwidth$

---

[8] 40dBm or 10 Watts is used as a worst-case scenario.

[9] ITU-R M.1461-1 page 9 (-6dB)

$$NF = 0.75dB$$

Then for On-Tune Condition:

$$I = P_T + G_T + G_R - L_T - L_R - L_P - FDR_{if} \quad (16)$$

$I = -3.7dBm, On - Tune\ Condition$

Where:

$I = -3.7dBm, Peak\ Power\ Input\ to\ Radar\ Receiver$

$P_T = 40dBm, Peak\ Power\ of\ WiMAX\ Transmitter$

$G_T = 18dBi, WiMAX\ Main\ Beam\ Antenna\ Gain$

$G_R = 45dBi, Radar\ Receive\ Antenna\ Gain$[10]

$L_T = 2dB, Loss\ of\ WiMAXTransmitter$

$L_R = 1.4dB, Insertion\ Loss\ of\ Radar\ Receiver$

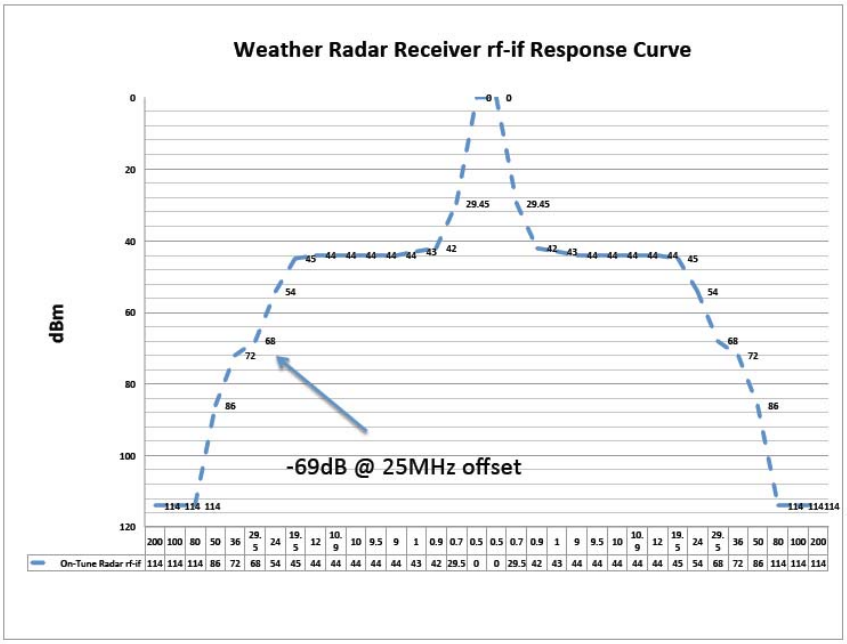
$L_P = 103.3dB, Propagation\ Path\ Loss\ between\ WiMAX\ \ and\ Radar\ Antennas$

$FDR_{if} = 0dB, On - Tune\ Condition$

For WiMAX Off-Tune condition of 25MHz:

$$I = P_T + G_T + G_R - L_T - L_R - L_P - FDR_{if} \quad (16.1)$$

[10] Main beam gain of radar antenna.



Weather Radar RF-IF Bandpass Filter Plot
[CTC alias notches for different clock frequencies (IF freq.) not shown]

Then from (16) above:

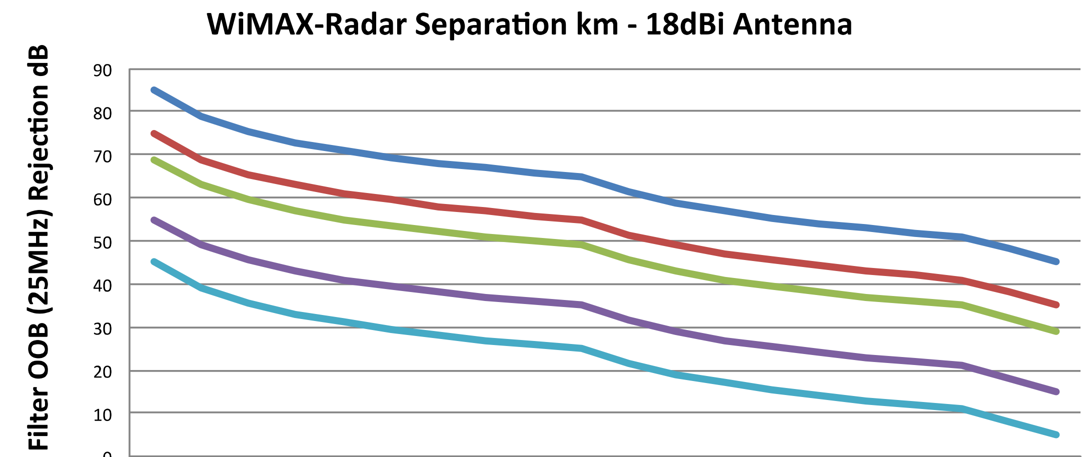
$I = (-3.7dBm) - FDR_{if}$

$I = (-3.7dBm) - (-69dB)$

$I = -65dB \ @ \ 25MHz \ Off - Tune$

Where:

$Radar\ FDR_{if}(25MHz)$ = -65dB @ 25MHz Off-Tune



	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.5	2	2.5	3	3.5	4	4.5	5	7	10
10 Watt Tx	85	79	75	73	71	69	68	67	66	65	61	59	57	55	54	53	52	51	48	45
1 Watt Tx	75	69	65	63	61	59	58	57	56	55	51	49	47	45	44	43	42	41	38	35
225mw Tx	69	63	59	57	55	53	52	51	50	49	45	43	41	39	38	37	36	35	32	29
10mw Tx	55	49	45	43	41	39	38	37	36	35	31	29	27	25	24	23	22	21	18	15
1mw Tx	45	39	35	33	31	29	28	27	26	25	21	19	17	15	14	13	12	11	8	5

Plot of Spatial Separation (km) with Calculated WiMAX Transmit Filter Rejection, 25MHz Offset, and 18dBi WiMAX Antenna Gain for Different WiMAX Transmitter RF Power Levels

Additional loss for 5km spatial separation (20log5) = 14dB

Thus,

$$-65dB + 14dB = -51.25dB(FDR_{if})@\,5km$$

Out of Band WiMAX Transmit Filter – Thus, the OOB WiMAX transmit filter must be 65dB at 25MHz offset for outside operation and a spatial separation of 1km, and 51.25dB with 5km separation, all with direct antenna coupling. We recommend 65dB rejection under the conditions analyzed to allow latitude for spatial separation.

3.3. Protection Criteria

As demonstrated above, frequency offset, geographic separation, power level adjustments, antenna gain selection and filtering capabilities are factors which can be used to mitigate harmful interference to commercial weather radars operating in the 3.5-3.6 GHz band from WiMAX operations in the partially overlapping 3.55-3.65 GHz band.

Recommendations

In summarizing the above calculated interference values between the WiMAX and the Weather Radar the following applies:

- We used a 1MHz bandwidth (-113.25dBm noise floor) for these calculations. Bandwidth corrections must be applied for the appropriate data bandwidths (WiMAX receiver bandwidths).
- We applied the maximum gain of the antennas, 45dB for the Weather Radar and 18dB for the WiMAX.
- The WiMAX to Weather Radar On-Tune requires a large spatial separation and is not considered applicable in any scenario of interoperability we can envision.
- The WiMAX and Radar needs to be spatially separated by 5km, and Off-Tuned, by at least 25MHz in frequency.
- The WiMAX Transmitter filter rejection at 1km is calculated to be 65dB, minimum.
- The rejection requirement can be lowered 14dB by 5km separation.
- De-coupling of the antenna beams will lower the possibility of WiMAX receiver overload.
- The WiMAX can “globally” be considered as a helicopter hovering at the tower height (AGL) over the local terrain in site-specific locations and will surely come in direct contact with the radar main beam if not accounted for in the WiMAX site planning analysis.
- Radar siting becomes more complex when the WiMAX infrastructure is already in place and must be accounted for in the FCC’s final rules. This problem needs to be solved locally by the parties involved.
- In complex scenarios, the WiMAX antenna may not be able to be pointed toward the Weather Radar due to separation requirements, leaving a gap in coverage that, if filled, will have to be accomplished with a low power repeater.
- WiMAX must employ DFS to determine if a radar system is operating in the WiMAX band. The DFS look-thru must be capable of detecting a radar RF pulse with PRI of 4 milliseconds and a 3db emission bandwidth of 2MHz.
- SAS must be employed in the WiMAX device and be used in conjunction with a location (GPS) database to control permission and operating parameters. WiMAX must be cataloged into the database at installation time.
- Dynamic Spectrum Access (DSA) must be employed in the WiMAX.
- In paragraph 3.3 of the ITU-R M.1461-1 document the receiver I/N ratio employed may be inappropriate for weather radar applications. The Weather Radar receiver integration ($\cong 32\ pulses$ displays targets ≅8dB below the IF noise level.

Respectfully submitted,
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William H. Walker
Vice President & Chief Engineer
Baron Services, Inc.

System Engineer with combined 50 years of experience in the design, and development of military and commercial electronic systems.

Relevant experience includes ground based, shipboard and airborne radar.

Designed and developed the 1st commercial Broadcast C-Band weather radar and Video Integrator Processor in 1970. Designed and developed the present line of weather radar systems for the Baron Services product line.

Most recently designed and developed the Dual-Polarization Upgrade for the NEXRAD Weather Radar.

Holds several International and US patents for Dual-Polarization Radar.

Previous Employment: Vitro Systems, Metric Systems, Enterprise Electronics Corporation, Signal Technology Corporation, and BAE Radar Systems.

Appendix A: S-Band Weather Radar Performance Characteristics

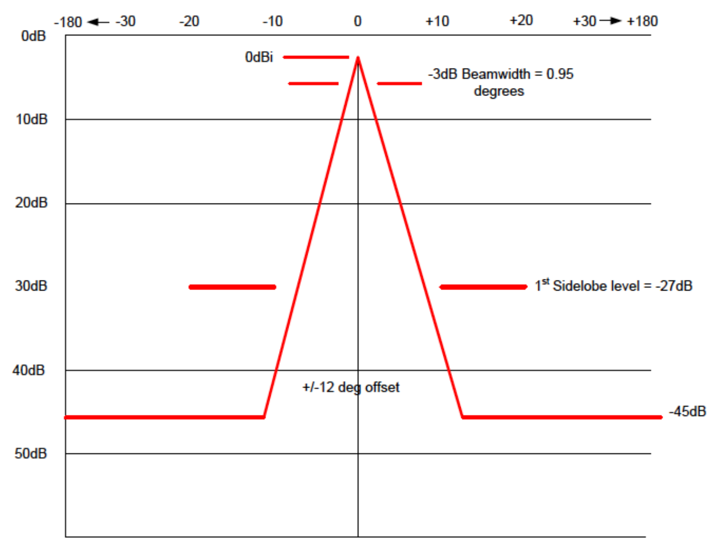
1.0 Table of Characteristics

The Baron Weather Radar System characteristics are virtually identical to NEXRAD, with which we are very familiar. The minor differences are in RF operating frequency, a variable pulse RF pulse width and a slightly higher average RF power at the output of the klystron flange. A table of the Baron weather radar characteristics follows.

KHDD-1000S-K/DP Weather Radar Characteristics		
Item	***Item***	***Item***
1	Radar Type	Continuous Surveillance Scanning - Range Gated Coherent Pulsed Doppler Weather Radar
2	Operating Frequency	Tunable, 3.5GHz to 3.6GHz
3	Transmitter Type	Pulsed Klystron Amplifier
4	Peak Power	1000kW, Tx Flange
5	Frequency Source	Crystal Controlled Phase Locked Loop
6	RF Duty Cycle	.00149 max = 333prf x 4.5usec pulse
7	Average Power	1490 Watts max, Klystron Flange
8	Tx Loss, 100ft tower typical	Single Horizontal Polarization, 3dB Dual Linear H&V Polarization, 6dB each
9	Pulse Width	2.0 to 4.5microseconds, Surveillance 0.8 to 1.2 Doppler Surveillance Software selectable by signal processor mode Occupied RF Bandwidth 11MHz in Narrow Pulse
10	Pulse Rate	Surveillance PRF 250-330pps Doppler Single PRF, 900-1300pps Doppler Dual-PRF, 2:3 ratio 600:900pps
11	Radar Receiver	Type Coherent Digital, 14bits or 16bits
12	System Noise Figure	1.75dB typical @ 290degK
13	Receiver Sensitivity *without Integration*	-113.25dBm in 1MHz bandwidth – proportional bandwidth = $1/\tau$ [-119dBm in 4.5usec pulse) Based on Single Pulse Detection Calculation
14	LNA	0.75db NF, 34dB Gain, P1dB = 13dBm
15	Pulses per Ray (.95deg)	Variable, 32 pulses typical
16	Linear Range	Digitizer >105dB
17	EMI Filter	Yes, see attached rf-IF bandpass plot for 1MHz
18	Antenna Type	Front-fed Parabolic Dual-Polarization Dish, see attached antenna pattern mask, same as NEXRAD
19	Gain	45dBi typical
20	Beam Width	-3dB = <1degree, 0.95 typical
21	Side lobes	See Antenna Pattern Mask, 1st Side lobe -27dB or 18dBi, sloping down to 0dBi at +/-12 degrees offset, 5dBi max lobe outside +/-12.5deg to +/-180 degrees

KHDD-1000S-K/DP Weather Radar Characteristics - continued		
Item	**Characteristic**	**Metric**
22	Polarization	Selectable Single Linear Horizontal Dual-Linear, Horizontal and Vertical
23	Scan Rate	6 RPM, 36deg/sec
24	Effective Radiated Power, 100ft tower typical	Main Lobe = Horizontal Polarization only – 73.7dBW/103.7dBm Dual-Polarization H&V– 70.7dBW/100.7dBm 1st Side Lobe = Horizontal Polarization only – 55.7dBW/85.7dBm Dual-Polarization H&V– 52.7dBW/82.7dBm H&V
25	Radiation Hazard Interlock Conditions, Radiation De-Energized	Tower Access Switch Radome Trap-Door Switch Positioner Safety Switch Antenna is Stopped for 30 Seconds

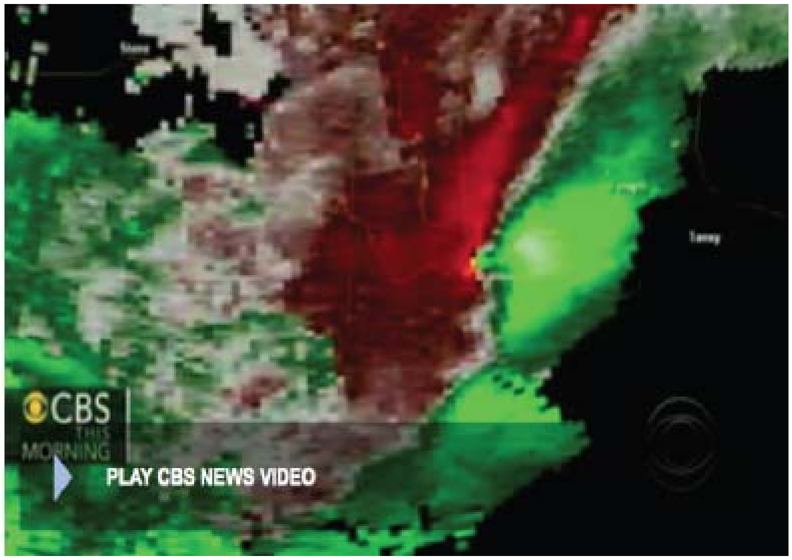
2.0 Weather Radar Antenna Pattern Mask



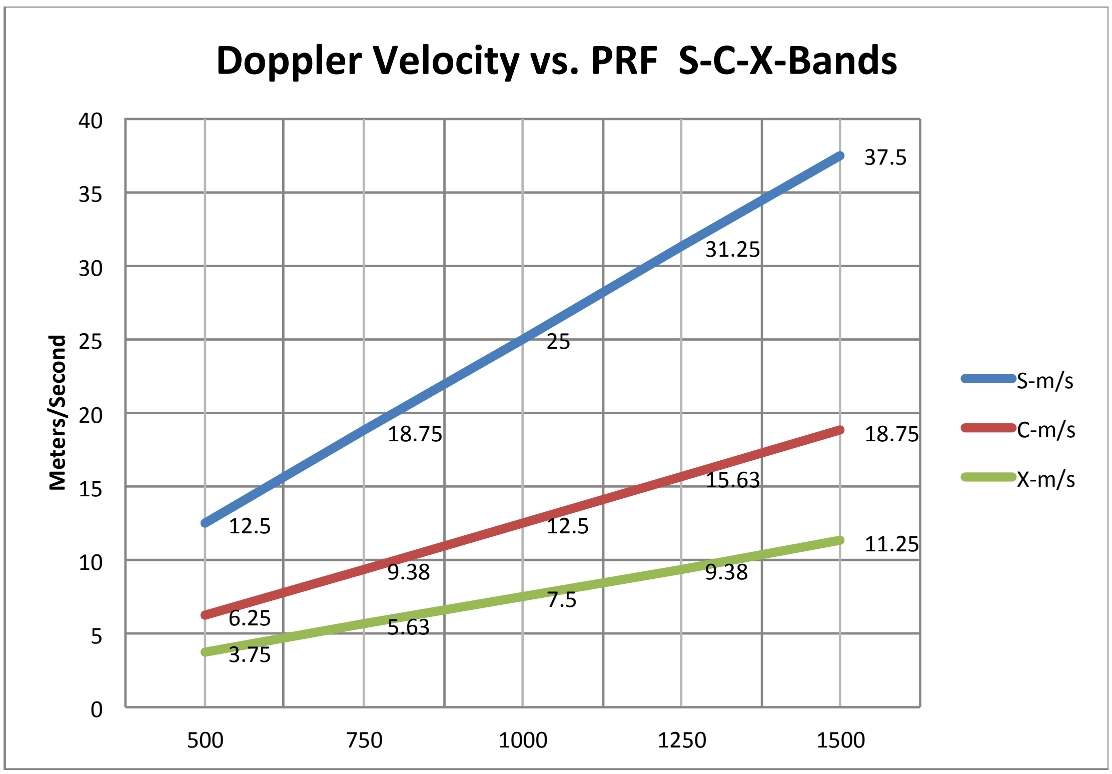
3.5GHz Antenna Pattern Mask

Baron Weather Radar Antenna Mask is the same as Designed and Verified for the NEXRAD Weather Radar. Antenna range measurements demonstrate the 1st side lobe with a 2dB margin worst-case or -29dBi vs. specified -27dBi.

3.0 Doppler Velocity



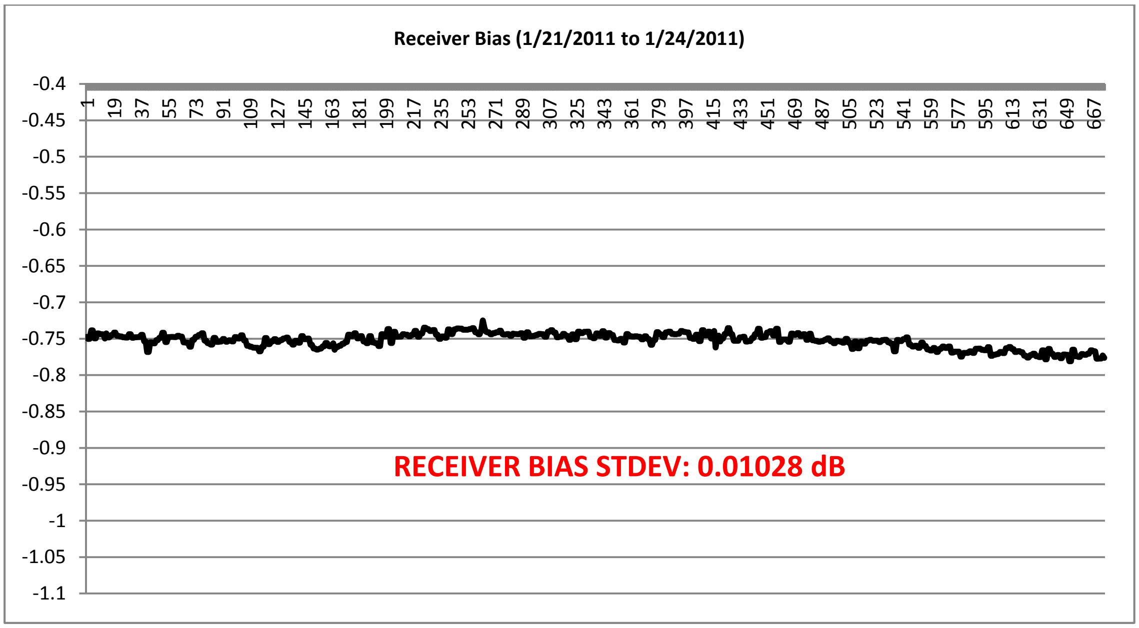
Weather Radar Has to Operate in the Rayleigh Region
And the Longer Wavelengths also Detect Higher Unambiguous Velocity



10cm, 5cm and 3cm Wavelength Vs. PRF Radar Velocity Plot

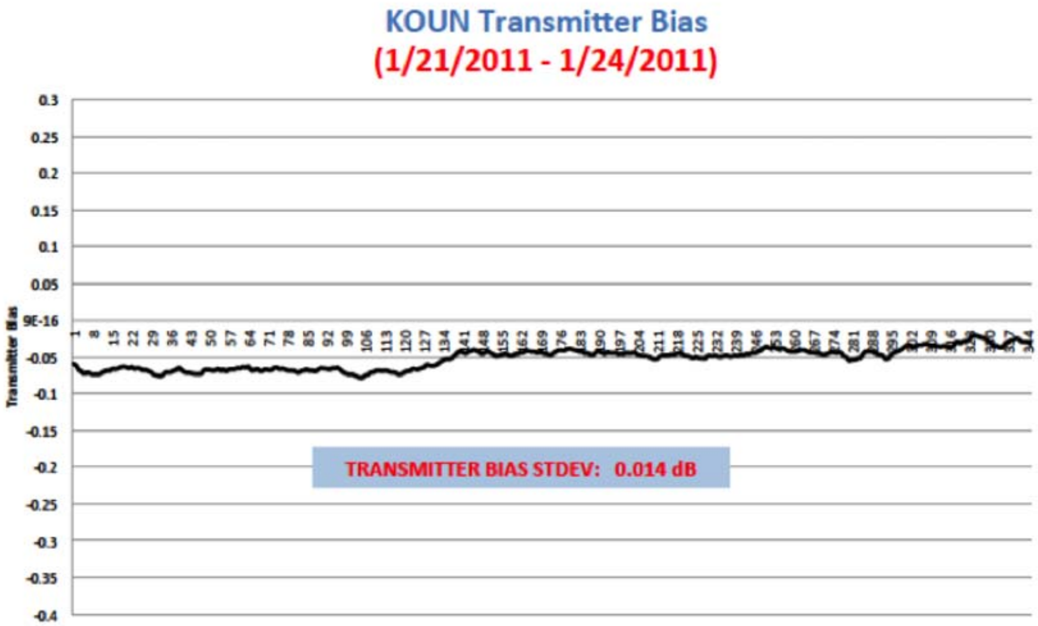
4.0 Dual-Polarization Weather Radar Precision and Stability

Dual-Polarization radar systems are quite possibly the most precise radar systems in the entire world, from the perspective of networks of operational radar systems. The largest example of this is the NEXRAD fleet of 171 systems. As an example of the precision and system stability, we are including the following bias plots of H&V polarization measurements, which demonstrate 1/100th dB stability and accuracy over a 3 day period.



On-Line "Real-Time" BITE Calibration H-V Receiver RF Bias Measurements Taken Every 5 Minutes over a Continuous Period of 3 days

Transmit Bias Calibration Data



On-Line "Real-Time" BITE Calibration H-V Transmitted RF Bias Measurements Taken Every 5 Minutes over a Continuous Period of 3 days

The complete calibration of the dual-pol radar H&V bias measurements, including dual-receiver linearity checks over a 103dB range, are accomplished in 3 seconds with the antenna in operation.

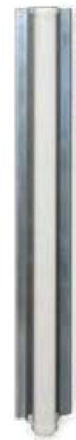
Unbalanced noise coupled to the antenna horizontal and/or vertical polarization terminals are problematic. The receiver bias calibration is offset by the noise and renders the weather data useless for the next 5 minutes duration, when another calibration is accomplished.

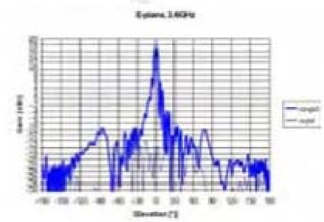
Appendix B: Laird WiMAX Antenna

ETSI CS3 High Gain VPOL 3.5GHz Sector Antenna

- Available in 60°, 90° or 120° beamwidths
- Up to 20dBi gain, low sidelobes
- Meets ETSI EN 302.85 CS3 pattern specifications
- Maximum null fill below horizon

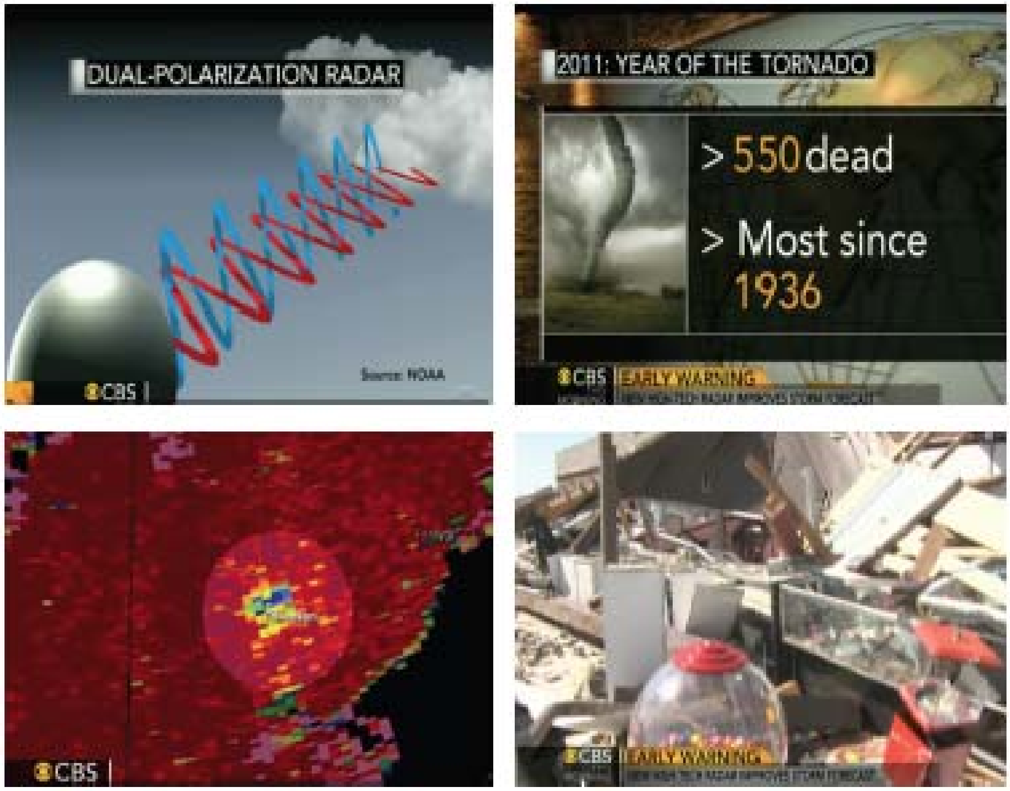
Specifications:	Part Number: J342xxV01-xxxN
Frequency Range	3400-3800 MHz
Gain (dBi)	20 (60°), 18.5 (90°), 17.5 (120°)
VSWR	< 1.7:1
Polarization	Vertical
Azimuth beamwidth	60°, 90° or 120°
Elevation beamwidth	3.5°
Null Fill	Down to -25°
Sidelobe Supression	>25 (60°), >28 (90°), >35 (120°)
Front -to-back Ratio	>35dB
Dimensions	52" x 6" x 3" (1321 x 152 x 76mm)





Antenna Used in Baron Interference Calculations

Appendix C: Weather Radar and Broadcasters Save Lives



Weather Radar is the Major Tool Used by Broadcasters to Warn US Citizens

See - *http://www.cbsnews.com/8301-505263_162-57388291/early-twister-detection-tech-gets-an-upgrade/?tag=morningLeadStoriesAreaMain;thisMorningLeadHero*